CH4RliE project

2D and 3D simulations with COMSOL

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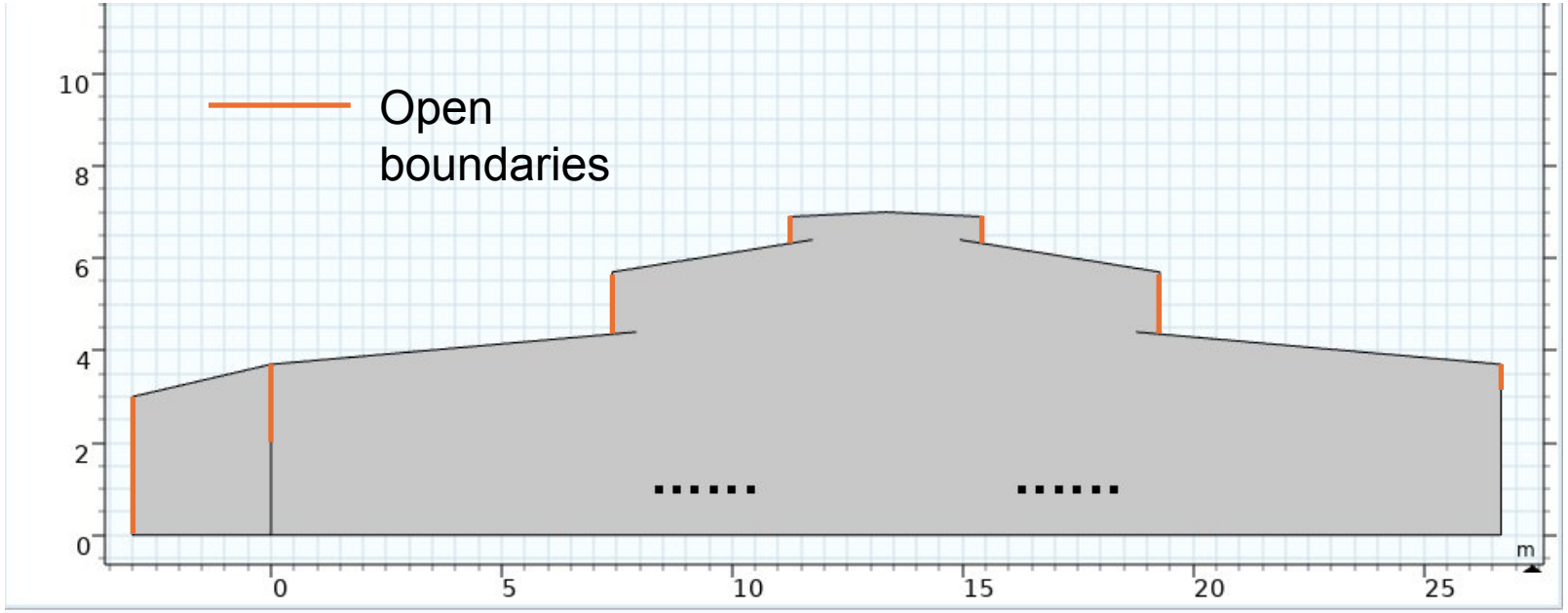
09/04/25

2D Geometry

Trasversal section

- Section passing through the center of the barn (30 m from the entrance)
- 12 cows producing the same amount of methane as the longitudinal simulations
- 1 m/s wind from both right to left and left to right
- 2 hours of simulation



2D Geometry

Trasversal section: Simulations

Simulations did not start under the same conditions as longitudinal geometry

Then it was chosen to change the type of mesh from the one used (very precise at the edges and less precise in the center) to a uniform one (less precise at the edges than the previous one and more precise in the center than the previous one)

A longitudinal simulation was carried out again to check whether the new mesh would lead to changes in the results

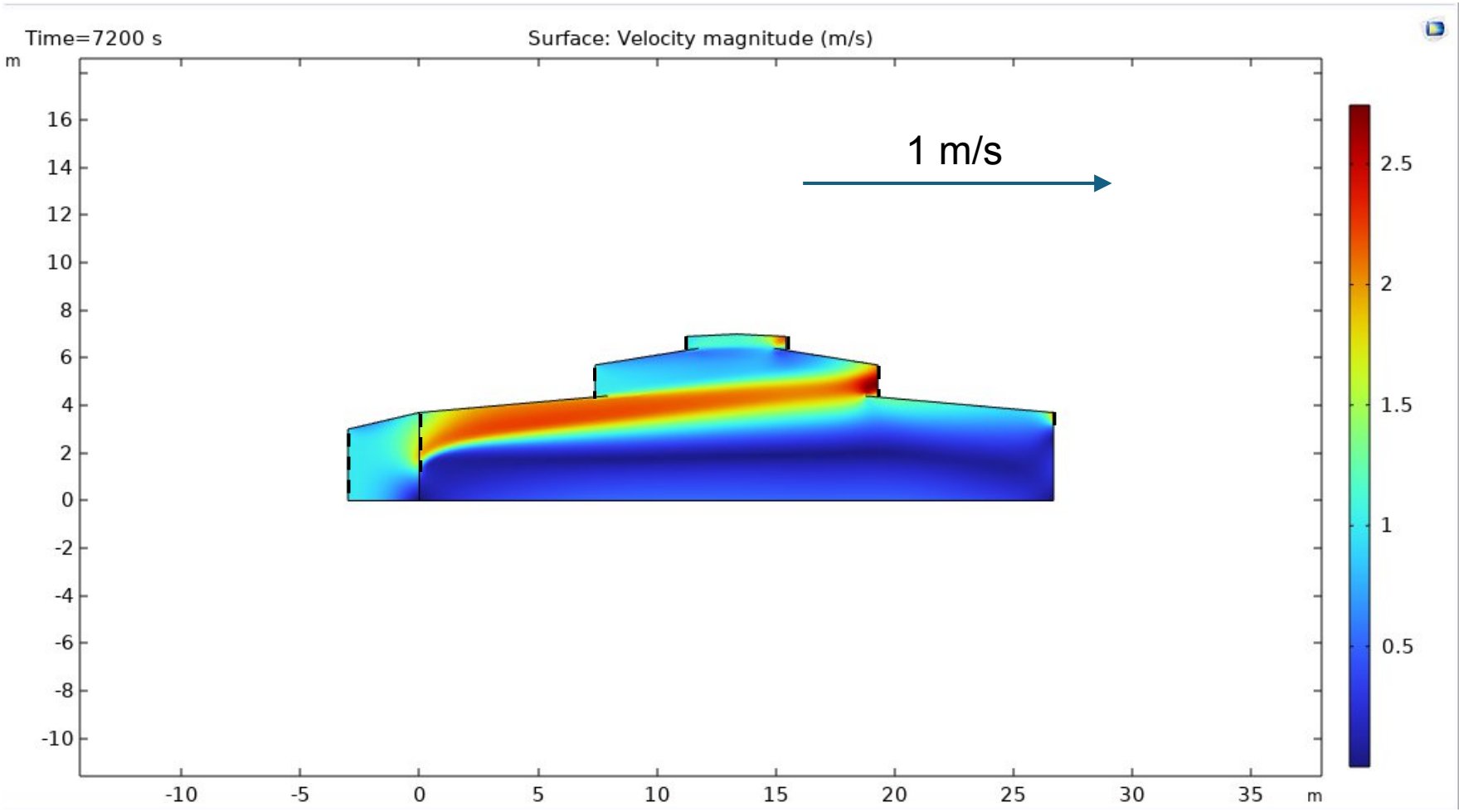
The results obtained were perfectly in line with those obtained previously

2D Geometry

Trasversal section: Simulations

- 1 m/s wind from left to right
- The ‘stationary’ situation is reached after about 5 minutes

Plot of the wind speed field

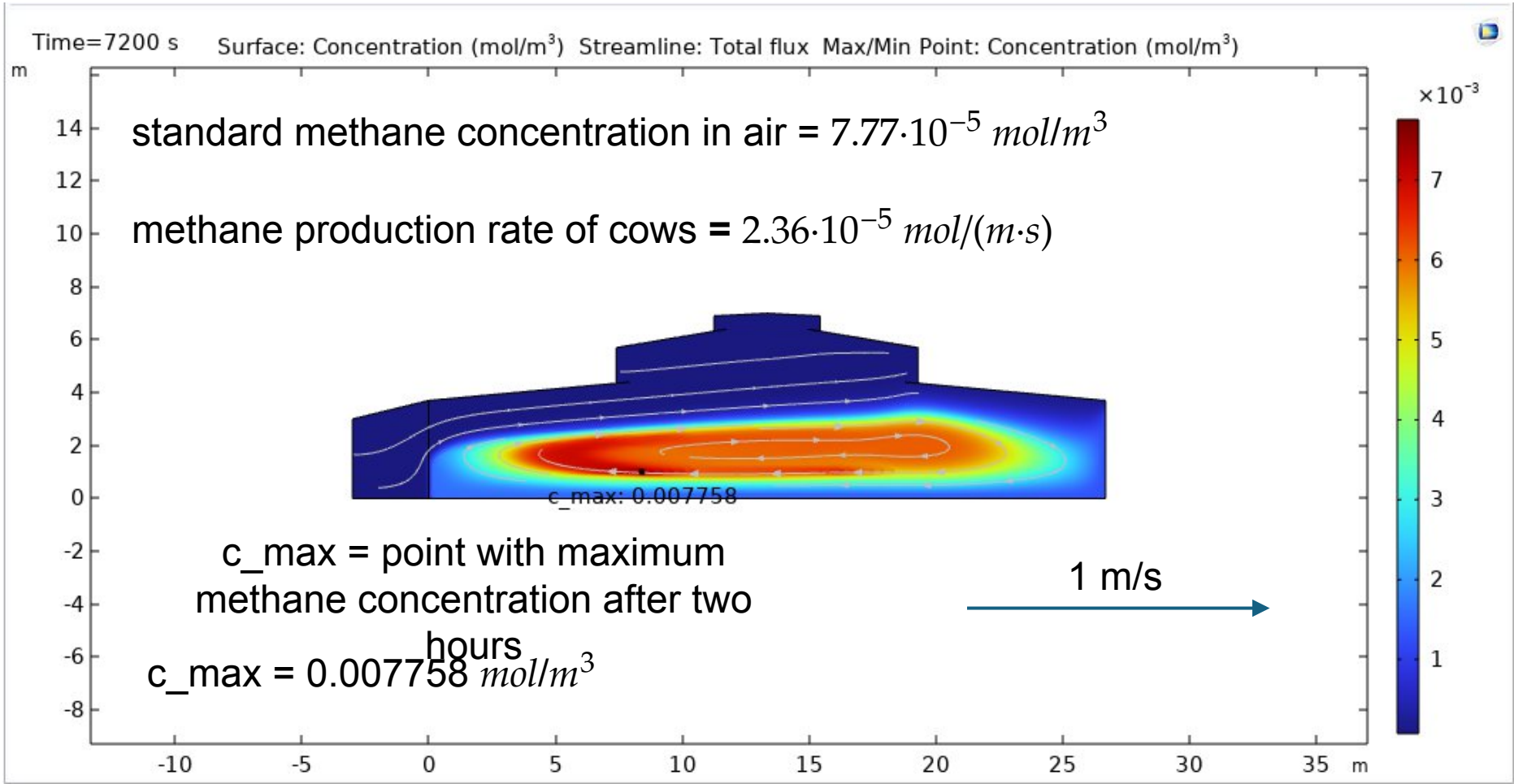


2D Geometry

Trasversal section: Simulations

- 1 m/s wind from left to right
- The ‘stationary’ situation is reached after about 5 minutes
- Methane accumulates in the lower part of the barn

Plot of methane concentration distribution



2D Geometry

Trasversal section: Simulations

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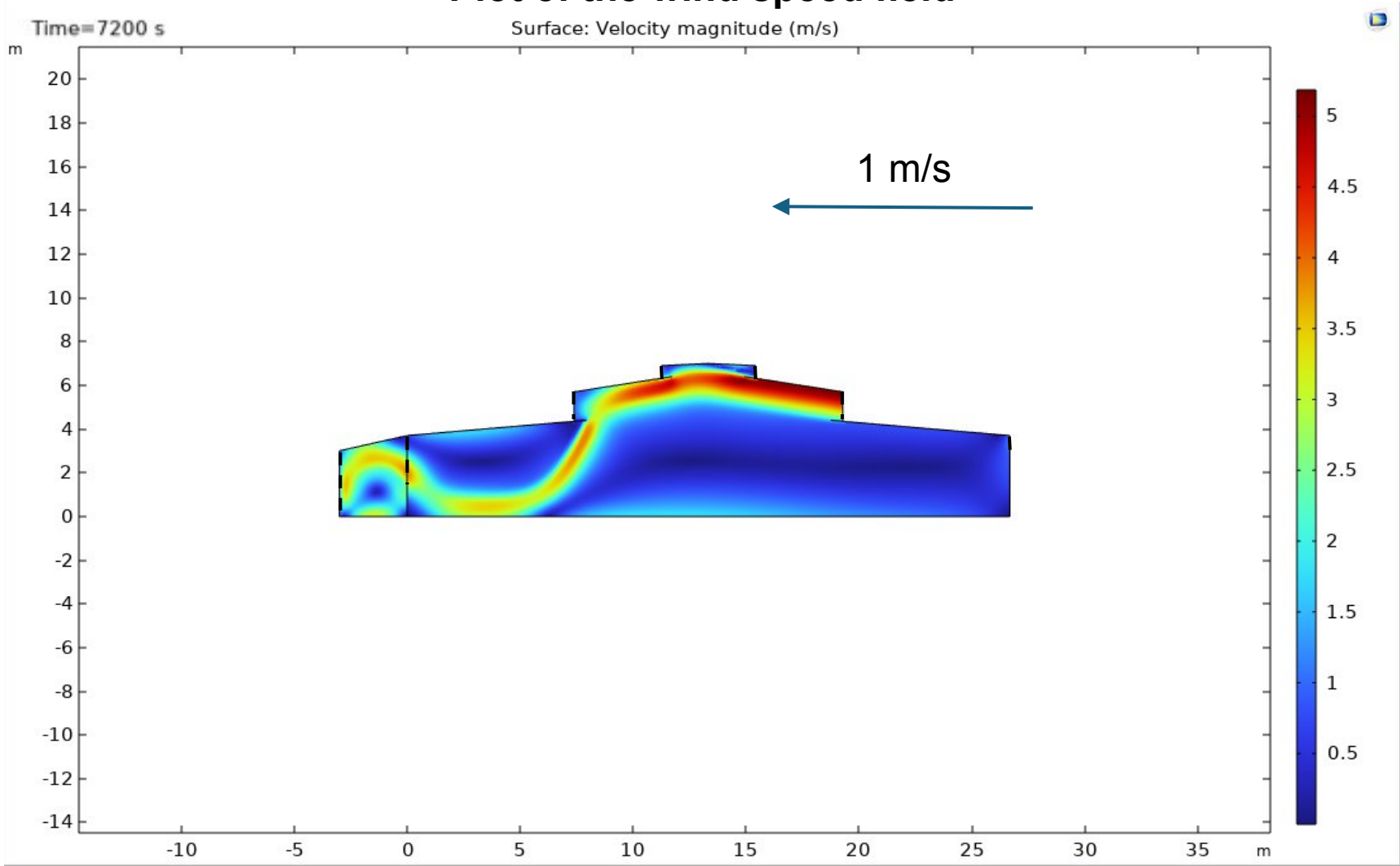

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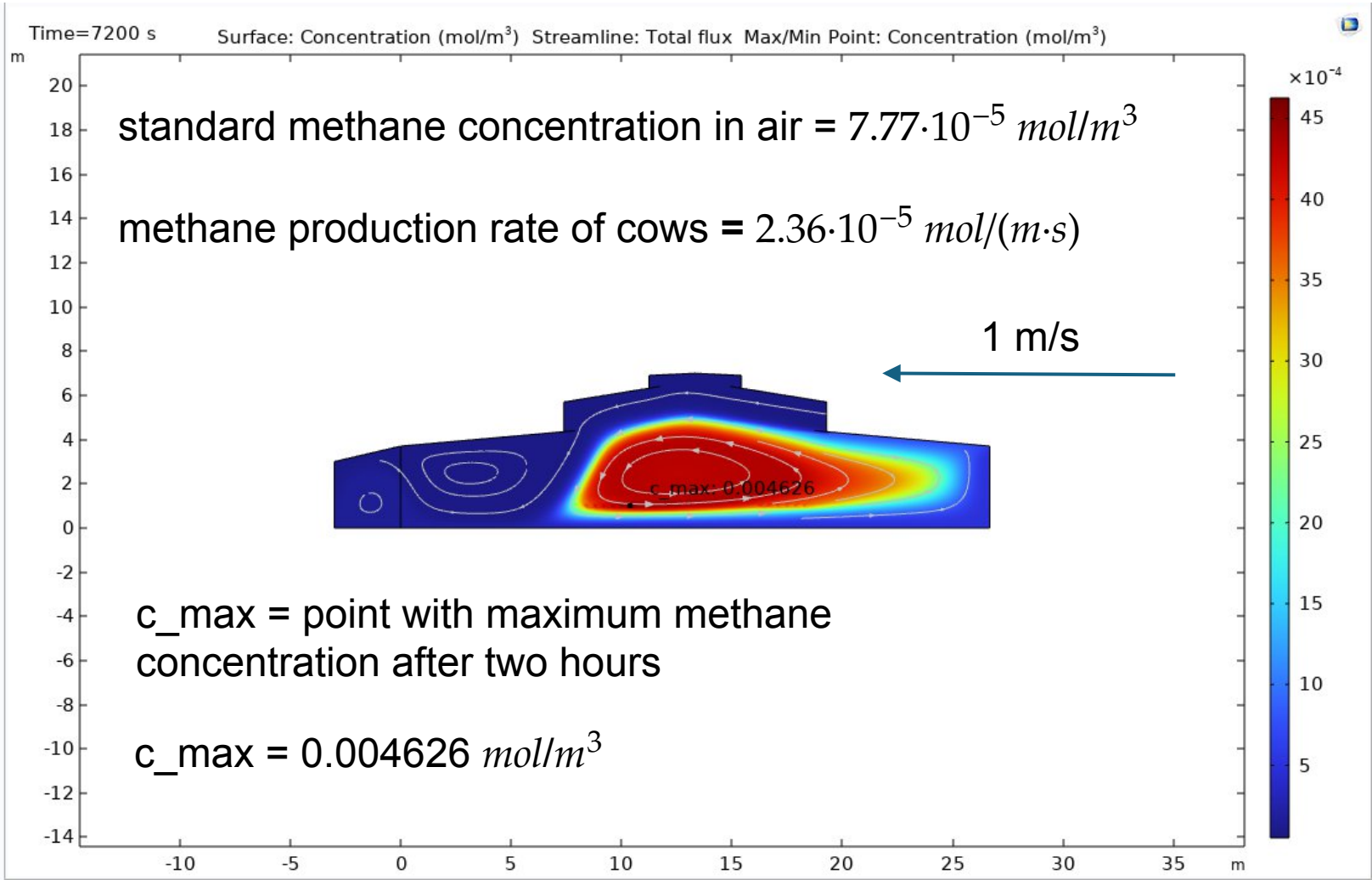
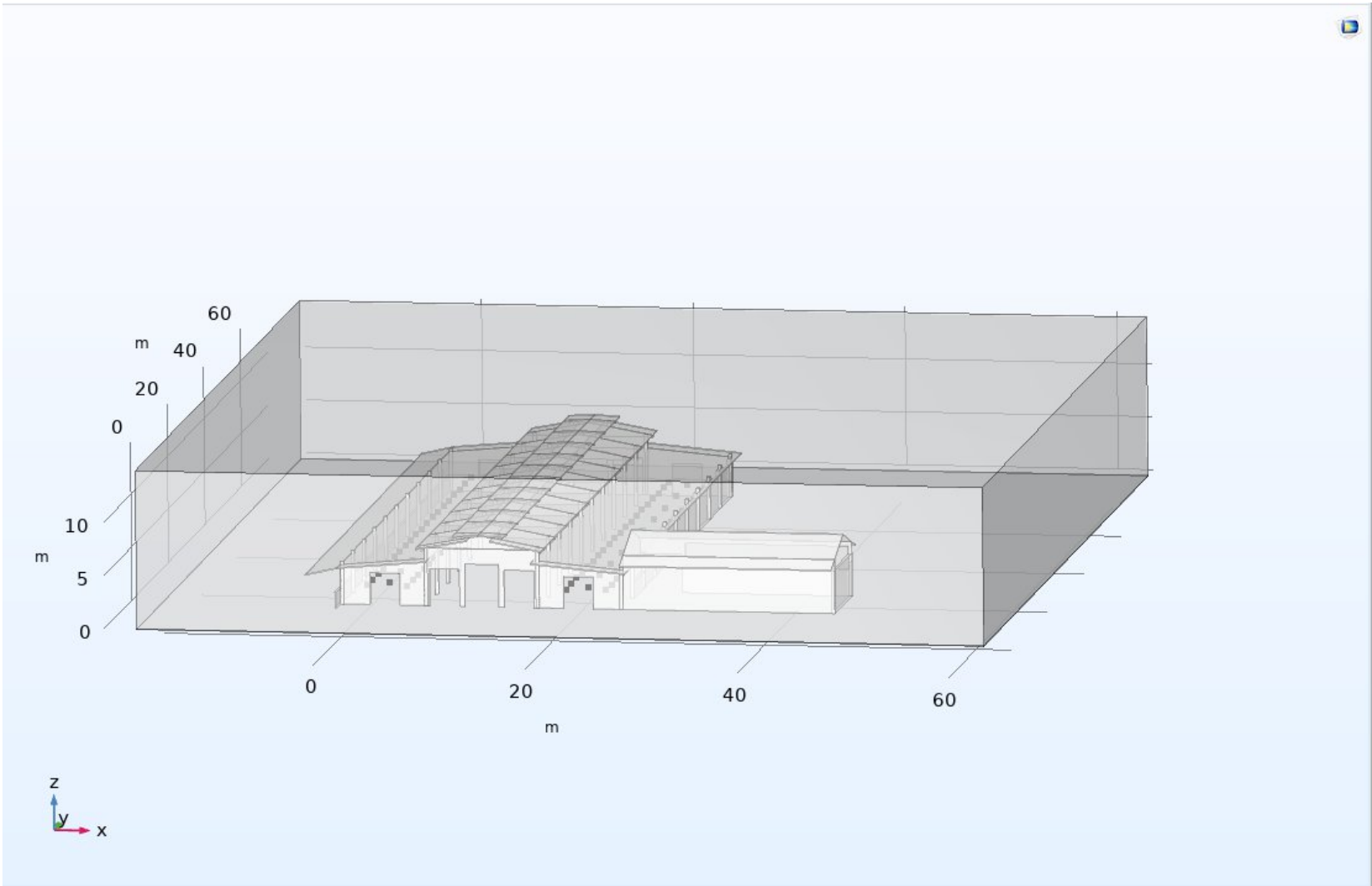


3D Geometry

Geometria completa

- 100 point cows (5 per bay) placed 1.5 m above the ground were simulated
- The parallelepiped volume is composed of air, while the floor is made of soil
- The mesh consists of bigger tetrahedra outside the barn and smaller tetrahedra inside



3D Geometry

Complete geometry : Only diffusion simulation

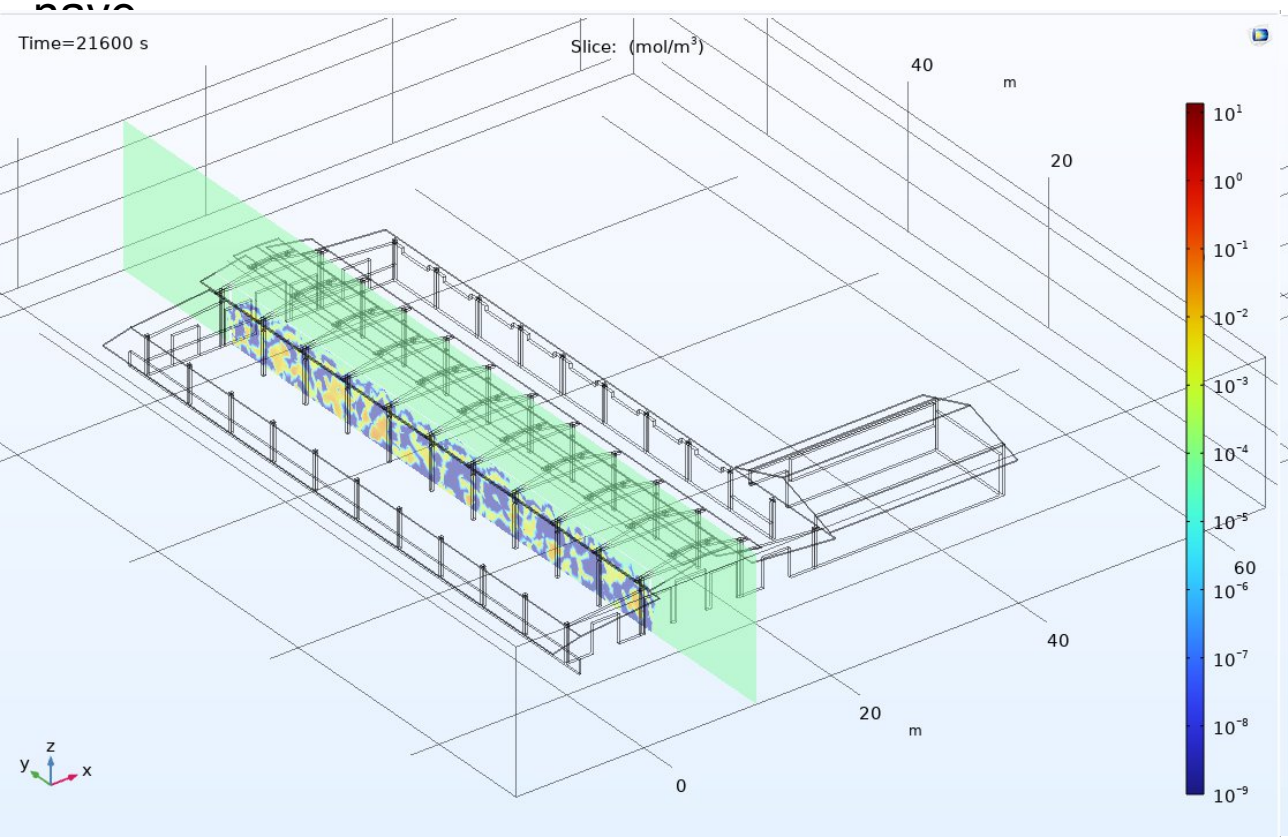
- Under these conditions COMSOL fails to simulate methane diffusion with wind turbulence physics simultaneously
- Initially, a 6-hour simulation was done in which only the physics of methane diffusion is present
- The methane production rate of the cows used is $q = 2.36 \cdot 10^{-4}\ mol/(m^2 \cdot s)$
- Methane concentration is represented on a logarithmic scale
- The plots shown highlight sections of the barn that might be of interest to us:
  - On the sides and in the center of the nave
  - Cross section at the center of the barn

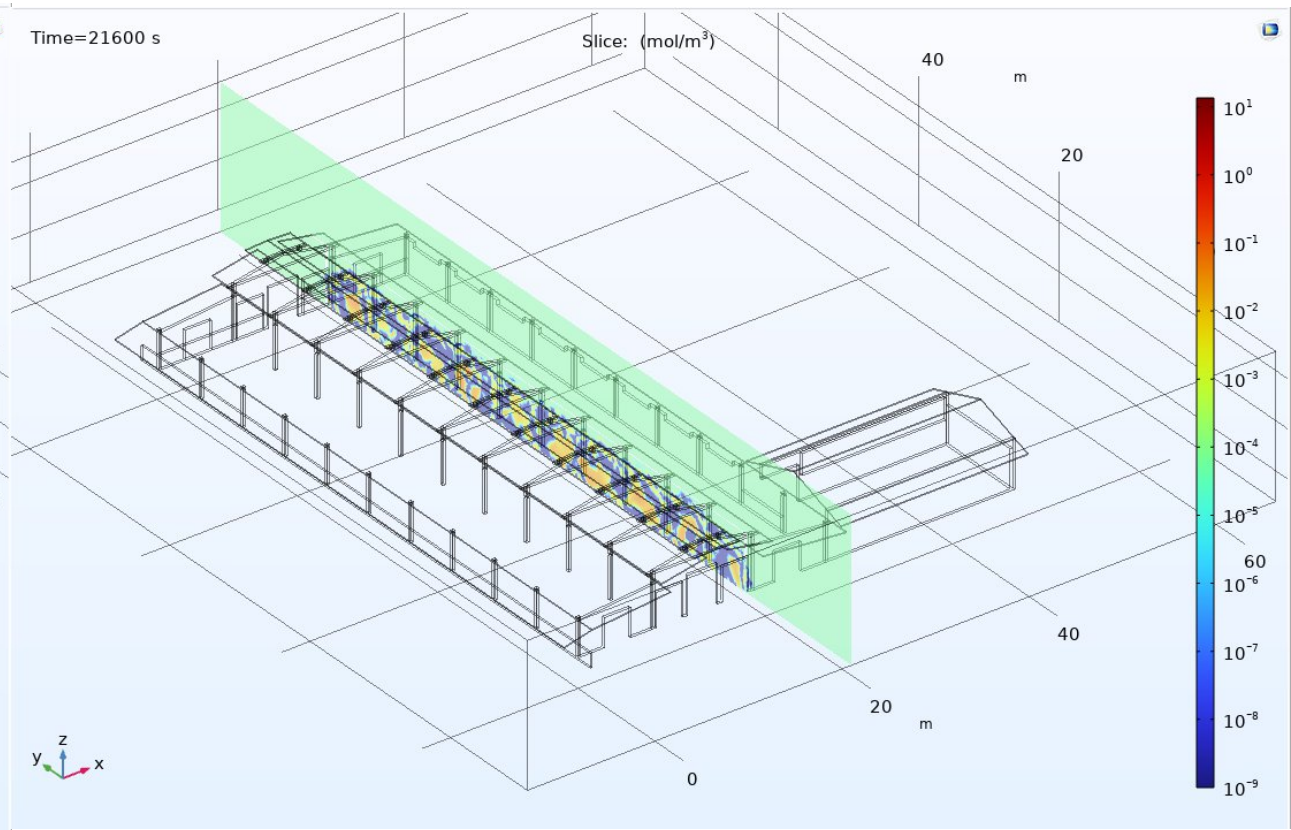
3D Geometry

Complete geometry : Only diffusion simulation

In these simulations COMSOL give us negative values of methane concentration in some points, that is meaningless

Sections on either side of the

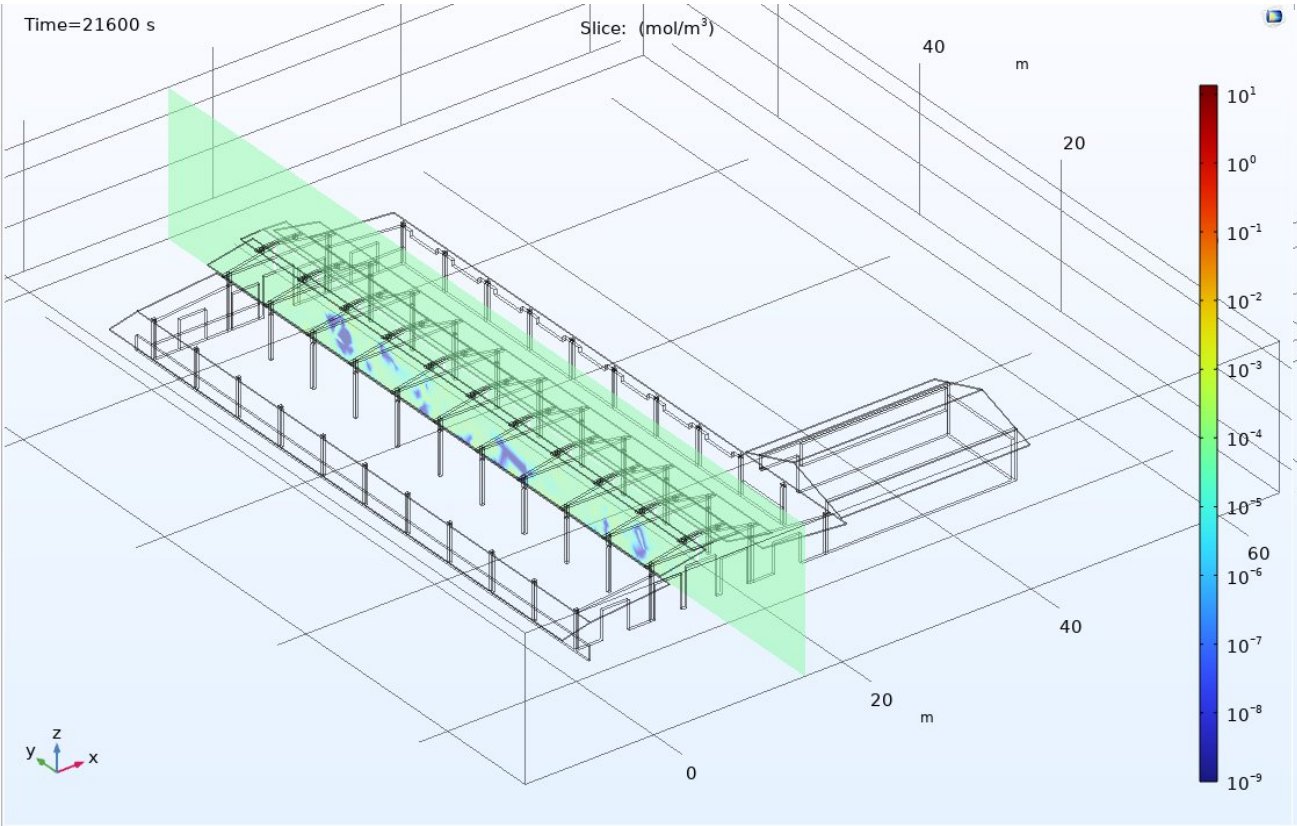




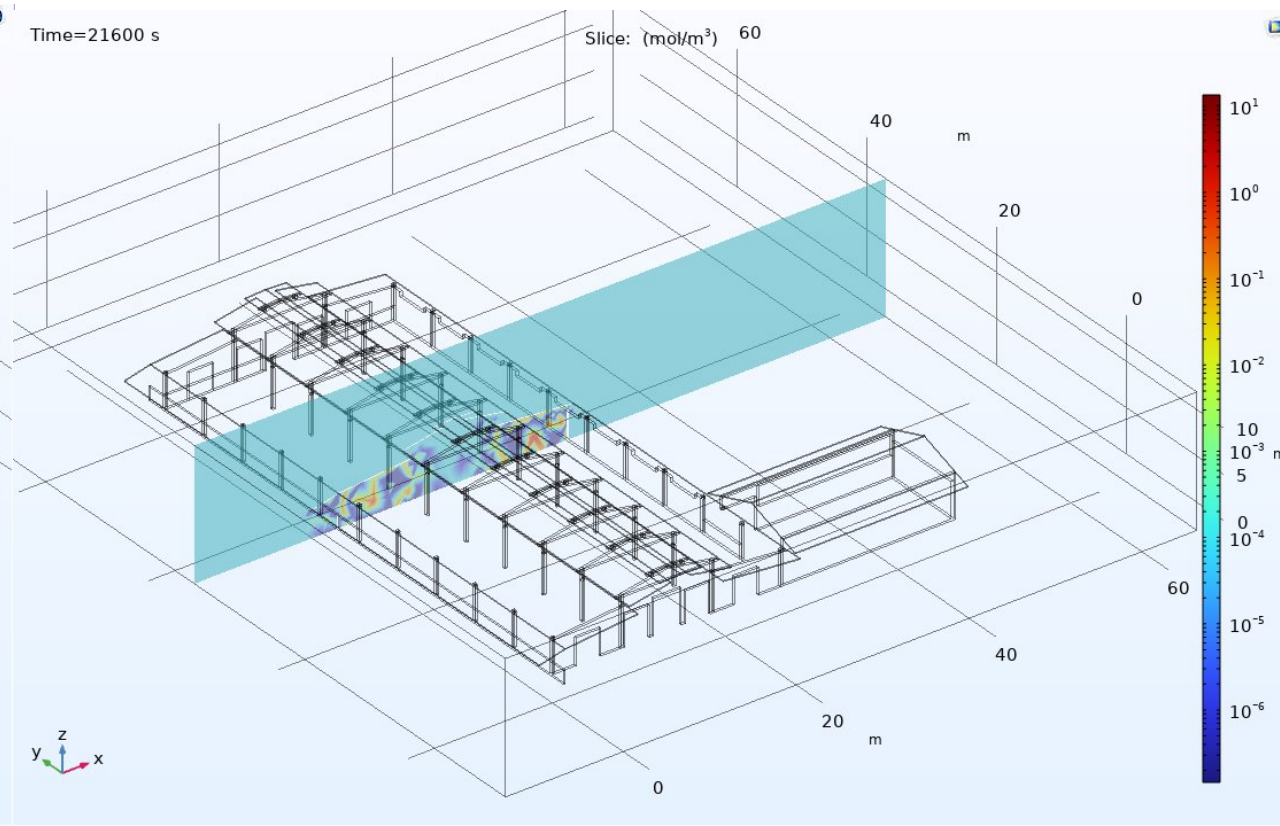
3D Geometry

Complete geometry : Only diffusion simulation

Section in the center of the nave



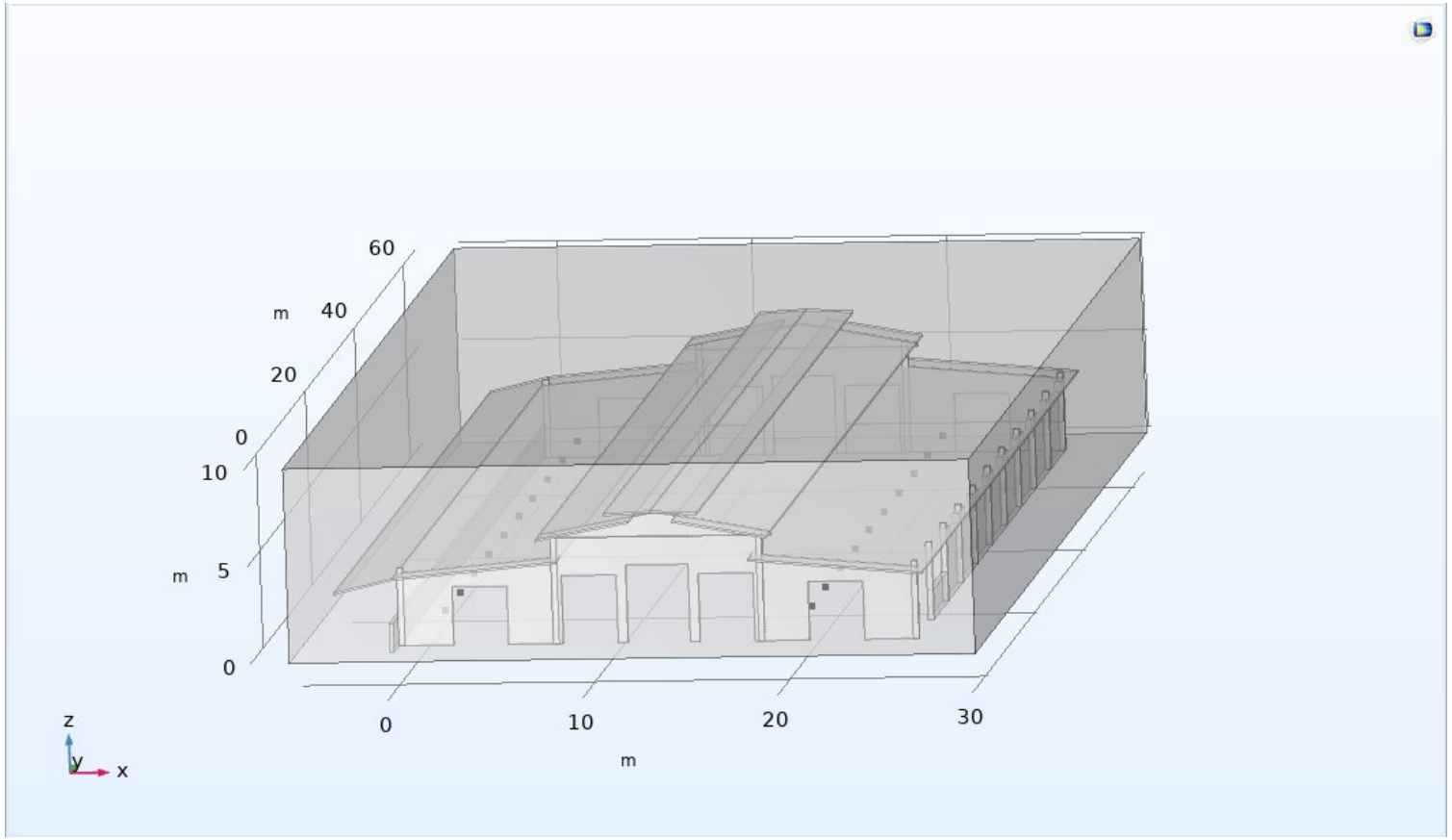
Trasversal section



3D Geometry

Simplified geometry

- 100 to 20 cows (1 per bay)
- Milking parlour eliminated
- Remove the beams and supports inside the barn
- Reduced the volume of air around the barn



3D Geometry

Simplified geometry: Diffusion and turbolence

- Even under these conditions, COMSOL cannot simulate diffusion and turbulence together right away because the physics differs greatly between the initial and final conditions of the simulation

- To solve, 3 simulations were run in succession in which the beginning of the next simulation coincides with the end of the previous one

  - 1° Sim: Diffusion and wind in laminar flow of 0.5 m/s (duration 30 min)

3D Geometry

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  - 1° Sim: Diffusion and wind in laminar flow of 0.5 m/s (duration 30 min) ⟶ Methane is produced as a wind with parallel flow lines enters from the front facade of the barn and exits from the back facade

3D Geometry

Simplified geometry: Diffusion and turbolence

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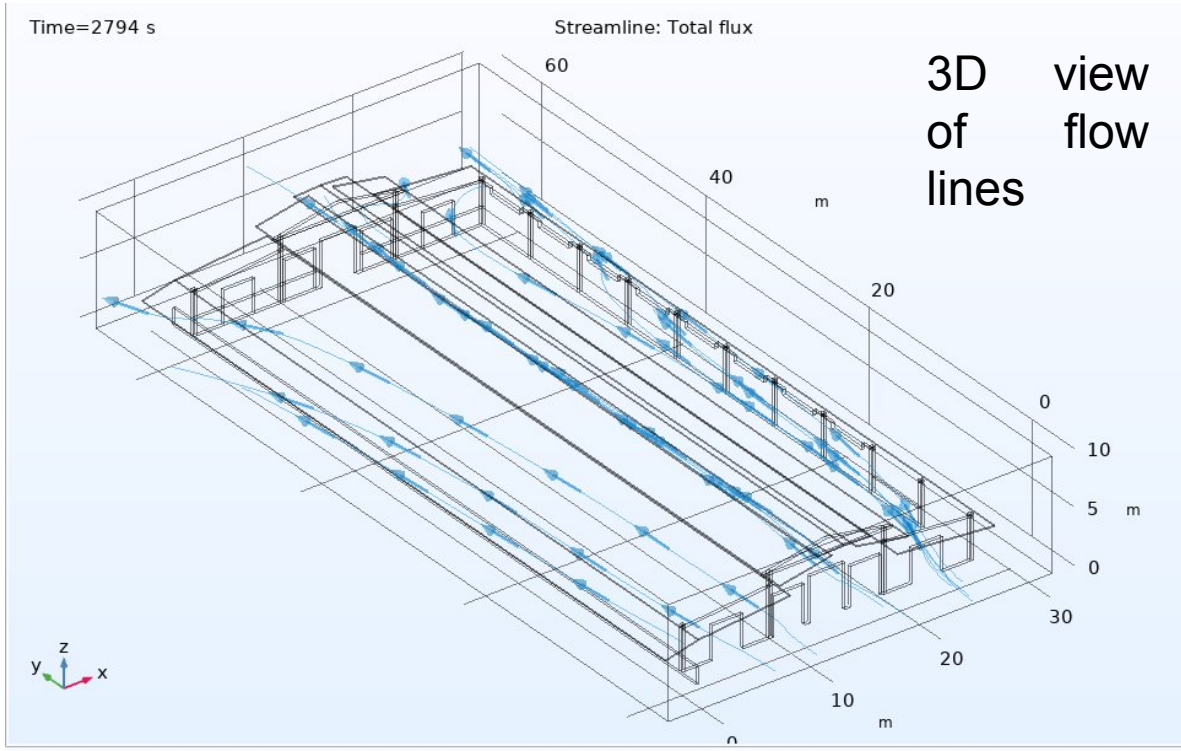
  - 1° Sim: Diffusion and wind in laminar flow of 0.5 m/s (duration 30 min)
  - 2° Sim: Diffusion and wind in turbulent flow of 0.5 m/s (duration 5 min)



3D view of flow lines

Flow lines are affected by turbulence, after 5 min a ‘stationary’ condition is reached and flow lines no longer change

3D Geometry

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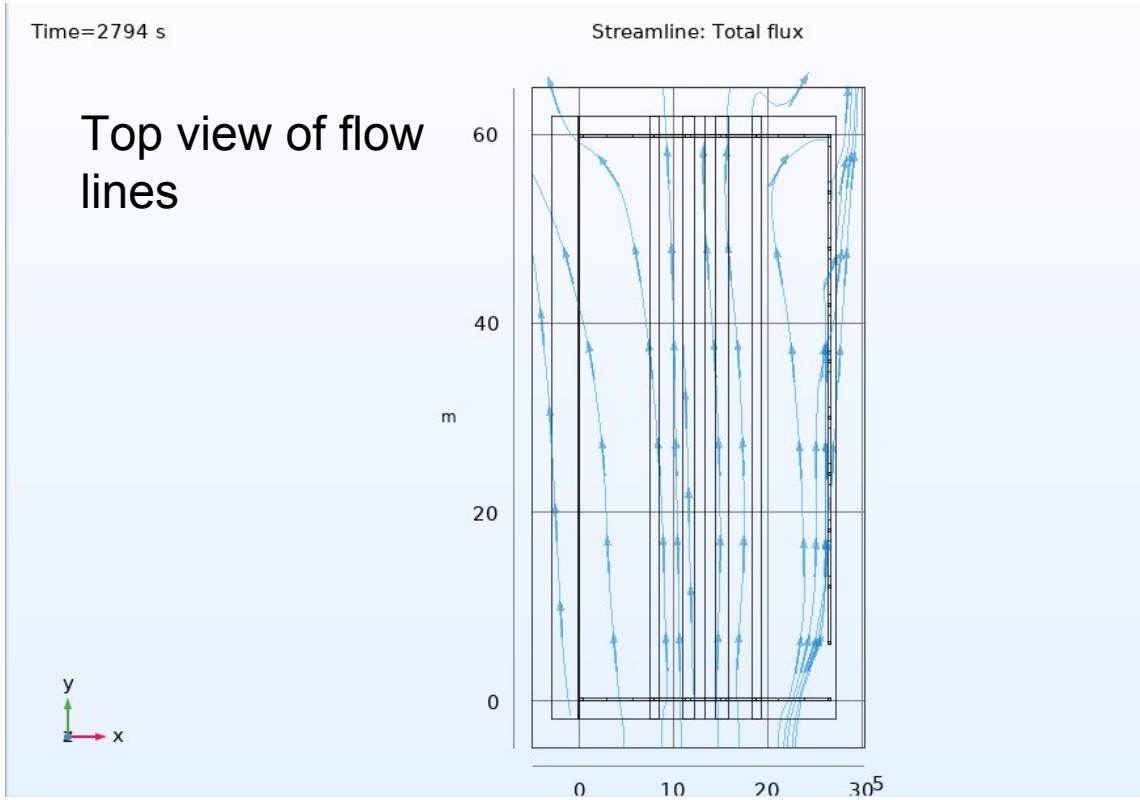
  - 1° Sim: Diffusion and wind in laminar flow of 0.5 m/s (duration 30 min)
  - 2° Sim: Diffusion and wind in turbulent flow of 0.5 m/s (duration 5 min)
  - 3° Sim: Diffusion and stationary wind of 0.5 m/s (duration 5 min)



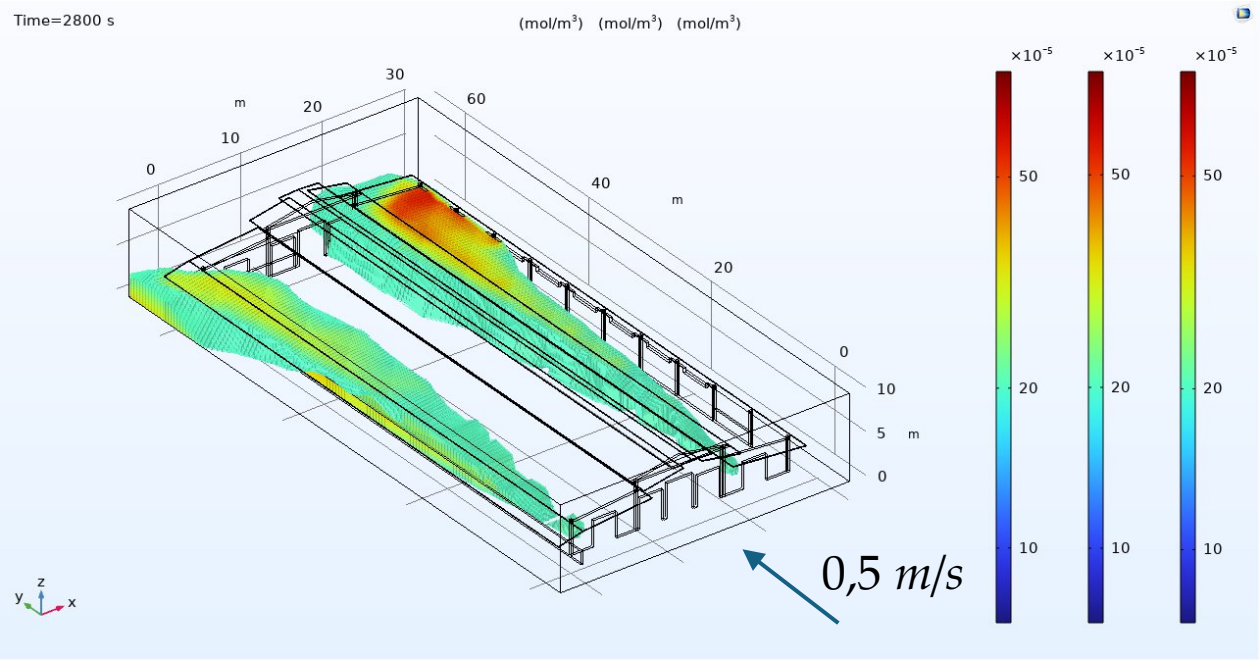
→ To lighten the simulation, turbulent motion is removed but the flow lines of the 2nd Sim are retained.

3D Geometry

Simplified geometry: Diffusion and turbolence, CH4 distribution

Plots were obtained by dividing each volume size into 100 slices, and then a threshold was set in the display range

CH4 concentration > $2{\cdot}10^{-4}\ mol/m^3$



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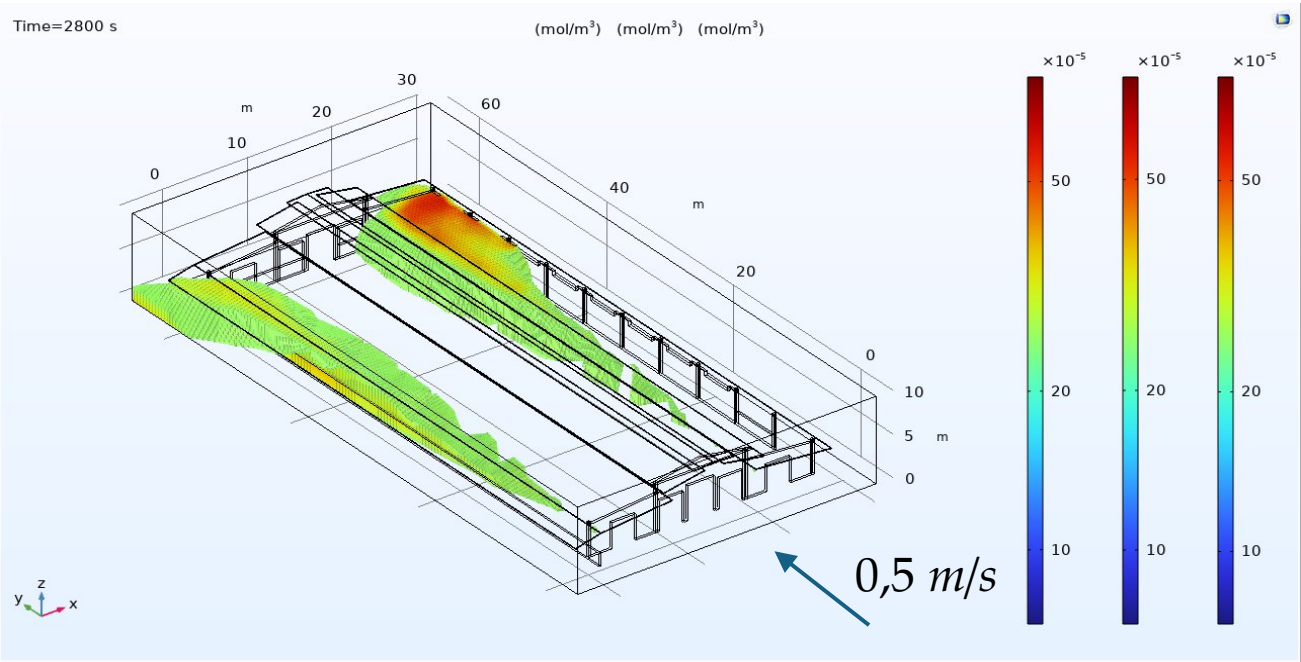
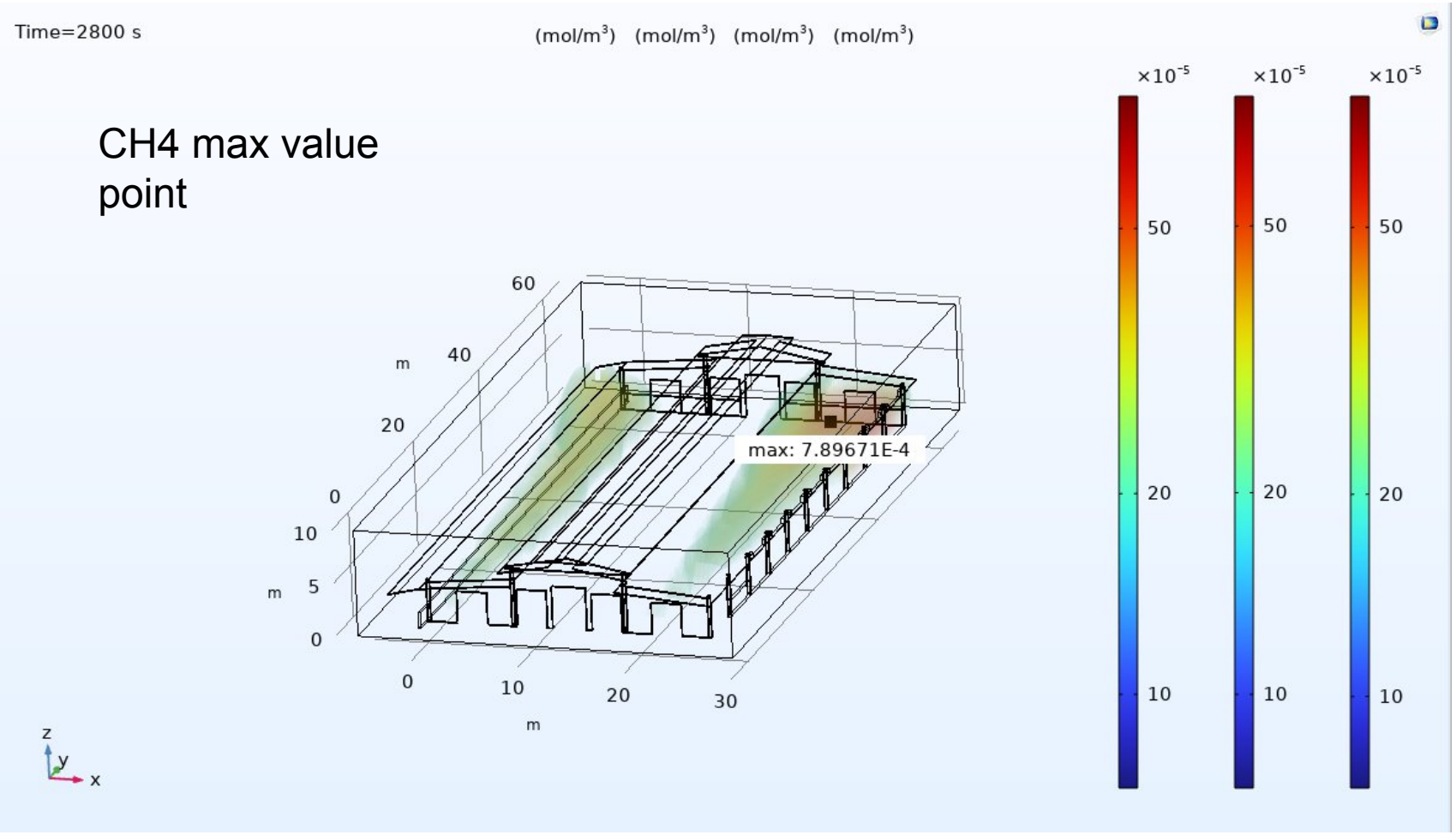


3D Geometry

Simplified geometry: Diffusion and turbolence, CH4 max value



Next steps

- Understanding the methane values obtained in the diffusion-only simulation
- Compare 2D simulations results with sliced sections of 3D simulations
- Change wind direction in 3D simulations
- Improving simplified geometry (increasing the number of cows)
- Slightly increase the turbulence time in 3D simulation